



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification: C01B 33/00		A2	(11) International Publication Number: WO 00/17103
			(43) International Publication Date: 30 March 2000 (30.03.2000)
(21) International Application Number: PCT/US99/21373		Published	
(22) International Filing Date: 17 September 1999 (17.09.1999)			
(30) Priority Data: 09/160,458 24 September 1998 (24.09.1998) US 60/101,046 18 September 1998 (18.09.1998) US			
(60) Parent Application or Grant MASSACHUSETTS INSTITUTE OF TECHNOLOGY [/]; O. BAWENDI, Moungi, G. [/]; O. JENSEN, Klavs, F. [/]; O. BAWENDI, Moungi, G. [/]; O. JENSEN, Klavs, F. [/]; O. NUGENT, Elizabeth, E. ; O.			
<p>(54) Title: INVENTORY CONTROL (54) Titre: GESTION D'INVENTAIRE</p> <p>(57) Abstract</p> <p>A novel encoding system, compositions for use therein and methods for determining the source, location and/or identity of a particular item or component of interest is provided. In particular, the present invention utilizes a collection of one or more sizes of populations of semiconductor nanocrystals having characteristic spectral emissions, to "track" the source or location of an item of interest or to identify a particular item of interest. The semiconductor nanocrystals used in the inventive compositions can be selected to emit a desired wavelength to produce a characteristic spectral emission in narrow spectral widths, and with a symmetric, nearly Gaussian line shape, by changing the composition and size of the semiconductor nanocrystal. Additionally, the intensity of the emission at a particular characteristic wavelength can also be varied, thus enabling the use of binary or higher order encoding schemes.</p> <p>(57) Abrégé</p> <p>L'invention concerne un nouveau dispositif de codage, des compositions associées utilisées et des procédés permettant de déterminer la source, l'emplacement et/ou l'identité d'un article ou d'un composant particulier. L'invention concerne notamment une collection d'au moins un effectif de populations de nanocristaux semi-conducteurs ayant des émissions spectrales caractéristiques, pour suivre la source ou l'emplacement d'un article d'intérêt ou pour identifier un tel article. Les nanocristaux utilisés dans les compositions selon l'invention peuvent être choisis pour émettre une longueur d'onde souhaitée afin de produire une émission spectrale caractéristique dans des largeurs spectrales étroites, et avec une caractéristique de ligne symétrique, quasi gaussienne, par le changement de la composition et des dimensions du nanocristal semi-conducteur. On peut en outre faire varier l'intensité de l'émission à une longueur d'onde caractéristique donnée, ce qui permet d'utiliser des programmes de codage d'ordre binaire ou supérieur.</p>			

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : C01B 33/00		A2	(11) International Publication Number: WO 00/17103 (43) International Publication Date: 30 March 2000 (30.03.00)
<p>(21) International Application Number: PCT/US99/21373 (22) International Filing Date: 17 September 1999 (17.09.99) (30) Priority Data: 60/101,046 18 September 1998 (18.09.98) US 09/160,458 24 September 1998 (24.09.98) US (71) Applicant (for all designated States except US): MASSACHUSETTS INSTITUTE OF TECHNOLOGY (US/US); 77 Massachusetts Avenue, Cambridge, MA 02142 (US). (72) Inventors; and (75) Inventors/Applicants (for US only): BAWENDI, Moungi, G. [-/US]; Apartment 2B, 285 Beacon Street, Boston, MA 02116 (US). JENSEN, Klavs, F. [-/US]; 103 Outlook Drive, Lincoln, MA 01773 (US). (74) Agent: NUGENT, Elizabeth, E.; Choate, Hall & Stewart, Exchange Place, 53 State Street, Boston, MA 02109 (US).</p>		<p>(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p>Published <i>Without international search report and to be republished upon receipt of that report.</i></p>	
<p>(54) Title: INVENTORY CONTROL</p> <p>(57) Abstract</p> <p>A novel encoding system, compositions for use therein and methods for determining the source, location and/or identity of a particular item or component of interest is provided. In particular, the present invention utilizes a collection of one or more sizes of populations of semiconductor nanocrystals having characteristic spectral emissions, to "track" the source or location of an item of interest or to identify a particular item of interest. The semiconductor nanocrystals used in the inventive compositions can be selected to emit a desired wavelength to produce a characteristic spectral emission in narrow spectral widths, and with a symmetric, nearly Gaussian line shape, by changing the composition and size of the semiconductor nanocrystal. Additionally, the intensity of the emission at a particular characteristic wavelength can also be varied, thus enabling the use of binary or higher order encoding schemes.</p>			

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Larvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav	TM	Turkmenistan
BF	Burkina Faso	GR	Greece		Republic of Macedonia	TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NB	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's	NZ	New Zealand		
CM	Cameroon		Republic of Korea	PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakhstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

Description

5

10

15

20

25

30

35

40

45

50

55

5

10

15

5

INVENTORY CONTROL

This invention was made with U.S. government support under Contract Number
20 94-00334 awarded by the National Science Foundation. The U.S. government has certain
rights in the invention

10

This application is a continuation-in-part of Serial No. 09/160,458, filed
25 September 24, 1998, and claims priority to the provisional application Serial No.
60/101,046 entitled "Inventory Control" filed on September 18, 1998. This application is
related to the following application that was filed on September 18, 1998: application
30 Serial No. 09/160,454 entitled "Biological Applications of Quantum Dots". Additionally,
this application is also related to the following application, which was filed on September
18, 1998: application Serial No. 09/156,863 entitled "Water Soluble Luminescent
Nanocrystals".

35 A portion of the disclosure of this patent document contains material that is subject
20 to copyright protection. The copyright owner has no objection to the reproduction by
anyone of the patent document or the patent disclosure, as it appears in the Patent and
40 Trademark Office patent file or records, but otherwise reserves all copyright rights
whatsoever.

25

45

Background of the Invention

50

The ability to track the location or identity of a component or item of interest has
presented a significant challenge for industry and science. For example, the demands of

55

5

2

10

keeping track of consumer products, such as items in a grocery store or jewelry, and the interest in identification devices, such as security cards, has led to the need for a secure and convenient system. Additionally, emerging technologies such as combinatorial chemistry, genomics research, and microfluidics also require the ability to identify and

15

5 track the location of large numbers of items.

20

A traditionally used method for tracking the location or identity of a component or item of interest is Universal Product Code technology, or barcode technology, which uses a linear array of elements that are either printed directly on an object or on labels that are affixed to the object. These bar code elements typically comprise bars and spaces, with 10 bars of varying widths representing strings of binary ones and spaces of varying widths representing strings of binary zeros. Bar codes can be detectable optically using devices such as scanning laser beams or handheld wands, or they can be implemented in magnetic media. The readers and scanning systems electro-optically decode the symbol to multiple alpha-numerical characters that are intended to be descriptive of the article or some 15 characteristic thereof. Such characters are typically represented in digital form as an input to a data processing system for applications in point-of-sale processing and inventory control to name a few.

25

30 Although traditional bar codes typically only contain five or six letters or digits, two dimensional barcodes have also been developed in which one-dimensional bar codes 35 are stacked with horizontal guard bars between them to increase the information density. For example, US 5, 304, 786 describes the use of a high density two-dimensional bar code 40 symbol for use in bar code applications. Unfortunately, although the information density of barcode technology has improved, this technology is often easily destructible, and the interference of dust, dirt and physical damage limits the accuracy of the information 45 acquired from the readout equipment. Additionally, because of the difficulty of etching the barcode on many items, it is also difficult to apply to a wide range of uses.

35

40 Another technology that has been developed for labeling objects includes a 45 composition comprising silicon or silicon dioxide microparticles and a powder, fluid or gas to be applied to objects such as vehicles, credit cards and jewelry (WO 95/29437). 50 This system typically allows the formation of 200 million particles on a single wafer, each

55

5

3

10 of the particles on one wafer being designed to be of identical shape and size so that when
the particles are freed from the wafer substrate one is left with a suspension containing a
15 single particle type which can thus be identified and associated with a particular item of
interest. This system, although information dense, is also not practical for a wide range of
20 application. One of the advantages explicitly stated in the application includes the
unlikely event of unauthorized replication of the particles because of the non-trivial
process of micromachining used that requires specialized equipment and skills. Thus, this
process would not be widely amenable to a range of uses for inventory control.

In addition to above-mentioned barcoding and microparticle inventory control
10 schemes, emerging technologies such as combinatorial chemistry have also resulted in the
25 development of various encoding schemes (See, for example, Czarnik, A.W., "Encoding
Methods for Combinatorial Chemistry", *Curr. Opin. Chem. Biol.*, 1997, 1, 60). The need
for this development has arisen in part from the split and pool technique utilized in
combinatorial chemistry to generate libraries on the order of one million compounds.

30 15 Split and pool synthesis involves dividing a collection in beads into N groups, where N
represents the number of different reagents being used in a particular reaction stage, and
after the reaction is performed, pooling all of these groups together and repeating the split
35 and pool process until the desired reaction sequence is completed. Clearly, in order to
keep track of each of the compounds produced from a reaction series, the beads must be
20 "tagged" or encoded with information at each stage to enable identification of the
compound of interest or the reaction pathway producing the compound. The tags used to
40 encode the information, however, must be robust to the conditions being employed in the
chemical synthesis and must be easily identifiable to obtain the information. Exemplary
encoding techniques that have been developed include the use of chemically robust small
45 25 organic molecules ("tags") that are cleaved from the bead after the synthesis is completed
and analyzed using mass spectroscopy. (US 5, 565, 324; US 5, 721, 099). The
disadvantage of this method is that the "tags" must be cleaved from the bead in order to
gain information about the identity of the compound of interest.

50 In response to this, several groups have developed encoding schemes that allow

55

5

4

10 analysis while the "tags" are still attached to the supports. For example, Radiofrequency
Encoded Combinatorial (RECTM) chemistry combines recent advances in microelectronics,
sensors, and chemistry and uses a Single or Multiple Addressable Radiofrequency Tag
15 (SMARTTM) semiconductor unit to record encoding and other relevant information along
the synthetic pathway (Nicolaou et al., *Angew. Chem. Int. Ed. Engl.* 1995, 34, 2289). The
disadvantage of this system, however, is that the SMARTTM memory devices utilized are
20 very large in size (mm), and thus scanning the bead to decode the information becomes
difficult. Another example of on-bead decoding includes the use of colored and
fluorescent beads (Egner et al., *Chem. Commun.* 1997, 735), in which a confocal
10 microscope laser system was used to obtain the fluorescence spectra of fluorescent dyes.
25 The drawback of this method, however, is the tendency of the dyes to undergo internal
quenching by either energy transfer or reabsorption of the emitted light. Additionally, this
system is not able to identify a range of dyes uniquely and distinctly.
Clearly, it would be desirable to develop a general information dense encoding
30 15 system flexible, robust and practical enough to be utilized both in general inventory
control and in emerging technologies. This system would also be capable of distinctly and
uniquely identifying particular items or components of interest.

35

20

Summary of the Invention

40 The present invention provides a novel encoding system and methods for
determining the location and/or identity of a particular item or component of interest. In
particular, the present invention utilizes a "barcode" comprising one or more particle size
45 25 distributions of semiconductor nanocrystals (also known as Quantum DotTM particles)
having characteristic spectral emissions to either "track" the location or source of a
particular item of interest or to identify a particular item of interest. The semiconductor
nanocrystals used in the inventive "barcoding" scheme can be tuned to a desired
50 wavelength to produce a characteristic spectral emission by changing the composition and

55

10 size, or size distribution, of the semiconductor nanocrystal. Additionally, the intensity of the emission at a particular characteristic wavelength can also be varied, thus enabling the use of binary or higher order encoding schemes. The information encoded by the 15 semiconductor nanocrystal can be spectroscopically decoded, thus providing the location, 5 source and/or identity of the particular item or component of interest.

In a particularly preferred embodiment, the method involves providing a 20 composition comprising an item of interest, and one or more compositions (e.g., composition of core and or shell), sizes or size distributions of semiconductor nanocrystals having characteristic spectral emissions, or providing a composition comprising a support, 10 an item of interest, and one or more sizes of semiconductor nanocrystals; subjecting said 25 composition to a primary light source to obtain the spectral emissions for said one or more sizes of semiconductor nanocrystals on said composition; and correlating said spectral emission with said item of interest. The present method, in preferred embodiments, can 30 be used to encode the identity of biomolecules, particularly DNA sequences, or other 15 items, including, but not limited to, consumer products, identification tags and fluids.

In another aspect, the present invention provides compositions. In one particularly preferred embodiment, the composition comprises a support, and one or more particle size 35 distributions of semiconductor nanocrystals having different characteristic spectral emissions. In another particularly preferred embodiment, the composition comprises a 20 support, one or more items of interest and one or more sizes of semiconductor nanocrystals having different characteristic spectral emissions. In yet another preferred 40 embodiment, the composition comprises an item of interest and one or more sizes of semiconductor nanocrystals having different characteristic spectral emissions. The 45 semiconductor nanocrystals can be associated with, attached thereto, or embedded within 25 said support structure. Additionally, the semiconductor nanocrystal can optionally have an overcoating comprised of a material having a band gap greater than that of the semiconductor nanocrystal.

In yet another aspect, the present invention provides libraries of compounds and/or 50 items of interest. In a particularly preferred embodiment, each compound in the library is 30 bound to an individual support, and each support has attached thereto or embedded therein

5

6

10

one or more identifiers comprising one or more particle size distributions of semiconductor nanocrystals having characteristic spectral emissions. In yet another preferred embodiment, each item of interest has attached thereto, or embedded therein one or more identifiers comprising one or more particle size distributions of semiconductor

15

5 nanocrystals having characteristic spectral emissions.

20

In yet another aspect, the present invention also provides kits for identifying an item of interest comprising a collection of items of interest, and wherein each member of said collection of objects has attached thereto or embedded therein one or more particle size distributions of semiconductor nanocrystals having characteristic spectral emissions.

25

10 In another preferred embodiment, the kit comprises a collection of items of interest, each bound to a solid support, wherein each support has attached thereto, associated therewith, or embedded therein one or more unique identifiers.

30

In another aspect, the present invention provides methods for identifying a compound having a particular characteristic of interest comprising providing a library of 15 compounds, testing said library of compounds for a particular characteristic of interest, observing the photoluminescence spectrum for each identifier attached to each support containing a compound of interest, and identifying the compound of interest by determining the reaction sequence as encoded by said one or more sizes of semiconductor 35 nanocrystals. In yet another particularly preferred embodiment, the step of identifying the 20 reaction sequence can be determined before testing the library of compounds because the reaction sequence can be recorded during the synthesis of the compound by "reading" the beads (i.e., observing the photoluminescence spectrum) prior to each reaction step to 40 record the reaction stages. The present invention additionally provides methods for recording the reaction stages of a synthesis concurrently with the synthesis.

45

25 In yet another aspect, the present invention provides methods for identifying a molecule having a characteristic of interest comprising contacting a first library of 45 molecules with a second library of molecules, wherein each of the molecules in the first library is encoded using one or more sizes of semiconductor nanocrystals and the second library has attached thereto or embedded therein one or more sizes of semiconductor 50 30 nanocrystals acting as "probes". This method provides simultaneously a way to identify

55

5

7

10

the binding of one or more molecules from the second library to the first library and determining the structure of said one or more molecules from the first library.

15

In one aspect of the invention a composition is provided comprising of one or more populations of member semiconductor nanocrystals, wherein each population has a 5 distinct characteristic spectral emission.

20

In another aspect of the invention, a composition is provided comprising the aforementioned populations of nanocrystals associated with a support.

25

In yet another aspect of the invention, a composition is provided comprising the aforementioned populations of nanocrystals associated with an item of interest, preferably 10 the nanocrystals are associated with a support.

30

In still another aspect of the invention, a library of compounds is provided, wherein each compound in the library is bound to an individual support, each support having associated therewith one or more populations of semiconductor nanocrystals, each population having distinct characteristic spectral emissions.

35

In a further aspect of the invention, a method is provided for identifying a compound having a characteristic of interest. The method comprises (a) providing a library of member compounds, wherein each member of said library of compounds is attached to a support, and wherein each support also has attached thereto or embedded therein one or more populations of semiconductor nanocrystals each population having 20 distinct characteristic spectral emissions, (b) testing each member of said library of compounds to identify compounds having a characteristic of interest, (c) subjecting each support to a light source to obtain the characteristic spectral emission, and (d) correlating the spectral emission with the identity of the compound having the characteristic of interest.

40

In yet a further aspect of the invention, a method is provided for identifying a molecule having a characteristic of interest. The method comprises (a) providing a first library of one or more member molecules, wherein each member of said first library is attached to a first support having attached thereto or embedded therein one or more first populations of semiconductor nanocrystals, each first population having a distinct 30 characteristic first spectral emission, (b) providing a second library of one or more

55

5

8

10

member molecules, wherein each member of said second library is attached to a second support having attached thereto or embedded therein one or more second populations of semiconductor nanocrystals, each second population having a distinct characteristic second spectral emission, and wherein the second spectral emission is distinct from the first spectral emission, (c) contacting said first library of molecules with said second library of molecules, and (d) observing the first and second spectral emissions, wherein said first and second spectral emissions provide information about which of the molecules from the second library of molecules are associated with said first library of molecules, and provides information about the identity of the molecule from said first library of molecules.

15

20

25

These and other embodiments and aspects of the present invention will readily occur to those of ordinary skill in the art in view of the disclosure herein.

30

15

Description of the Drawing

35

The file of this patent contains at least one drawing executed in color. Copies of this patent with color drawing(s) will be provided by the Patent and Trademark Office upon request and payment of the necessary fee.

40

20 Figure 1 depicts a color photograph of several suspensions of different sizes of ZnS overcoated CdSe semiconductor nanocrystals in hexane, illustrating the wide range of colors that can be utilized in the present invention.

45

Figure 2 depicts a general displacement reaction to modify the surface of the semiconductor nanocrystal.

50

25 Figure 3 depicts the use of the inventive system in fluid dynamics.

Figure 4 depicts the use of the inventive system in the identification of an object of interest.

Figure 5 depicts the use of the inventive system in the encoding of combinatorial libraries.

55

30

Description of Certain Preferred Embodiments**Definitions and nomenclature:**

15 Before the present invention is disclosed and described in detail, it is to be understood that this invention is not limited to specific assay formats, materials or reagents, as such may, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting.

20 It must be noted that, as used in the specification and the appended claims, the singular forms "a," "an" and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a nanocrystal" includes more than one nanocrystal, reference to "an oligonucleotide" includes more than one such oligonucleotide, and the like.

25 In this specification and in the claims that follow, reference will be made to a number of terms that shall be defined to have the following meanings:

30 "Quantum Dot™ particle": As used herein, the term "Quantum Dot™ particle" includes a semiconductor nanocrystal with size dependent optical and electrical properties. In particular, the band gap energy of a semiconductor nanocrystal varies with the 35 diameter of the crystal.

40 "Semiconductor nanocrystal" includes, for example, inorganic crystallites between about 1 nm and about 1000 nm in diameter, preferably between about 2 nm and about 50 nm, more preferably about 5 nm to about 20 nm (such as about 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, or 20 nm) that includes a "core" of one or more first semiconductor 45 materials, and which may be surrounded by a "shell" of a second semiconductor material. A semiconductor nanocrystal core surrounded by a semiconductor shell is referred to as a "core/shell" semiconductor nanocrystal. The surrounding "shell" material will preferably have a bandgap greater than the bandgap of the core material and can be chosen so to have 50 an atomic spacing close to that of the "core" substrate. The core and/or the shell can be a

5

10

10

semiconductor material including, but not limited to, those of the group II-VI (ZnS, ZnSe, ZnTe, CdS, CdSe, CdTe, HgS, HgSe, HgTe, MgTe and the like) and III-V (GaN, GaP, GaAs, GaSb, InN, InP, InAs, InSb, AlAs, AlP, AlSb, AlS, and the like) and IV (Ge, Si, Pb and the like) materials, and an alloy thereof, or a mixture thereof.

15

5 A semiconductor nanocrystal is, optionally, surrounded by a "coat" of an organic capping agent. The organic capping agent may be any number of materials, but has an affinity for the semiconductor nanocrystal surface. In general, the capping agent can be an isolated organic molecule, a polymer (or a monomer for a polymerization reaction), an inorganic complex, and an extended crystalline structure. The coat is used to convey 10 solubility, e.g., the ability to disperse a coated semiconductor nanocrystal homogeneously into a chosen solvent, functionality, binding properties, or the like. In addition, the coat 25 can be used to tailor the optical properties of the semiconductor nanocrystal.

25

"Identification unit or barcode": As used herein, the term "identification unit" is used synonymously with the term "barcode", and comprises one or more sizes of 30 semiconductor nanocrystals, each size of semiconductor nanocrystal having a characteristic emission spectrum. The "identification unit" or "barcode" enables the determination of the location or identity of a particular item or matter of interest.

35

"Item of interest": As used herein, the term "item of interest" is used synonymously with the term "component of interest" and refers to any item, including, but 20 not limited to, consumer item, fluid, gas, solid, chemical compound, and biomolecule.

40

"Biomolecule": As used herein, the term "biomolecule" refers to molecules (e.g., proteins, amino acids, nucleic acids, nucleotides, carbohydrates, sugars, lipids, etc.) that are found in nature.

50

The terms "polynucleotide," "oligonucleotide," "nucleic acid" and "nucleic acid 25 molecule" as used herein to include a polymeric form of nucleotides of any length, either ribonucleotides or deoxyribonucleotides. This term refers only to the primary structure of the molecule. Thus, the term includes triple-, double- and single-stranded DNA, as well as triple-, double- and single-stranded RNA. It also includes modifications, such as by methylation and/or by capping, and unmodified forms of the polynucleotide.

55

5

11

10

More particularly, the terms "polynucleotide," "oligonucleotide," "nucleic acid" and "nucleic acid molecule" include polydeoxyribonucleotides (containing 2-deoxy-D-ribose), polyribonucleotides (containing D-ribose), any other type of polynucleotide which is an N- or C-glycoside of a purine or pyrimidine base, and other polymers containing 5 nonnucleotidic backbones, for example, polyamide (e.g., peptide nucleic acids (PNAs)) and polymorpholino (commercially available from the Anti-Virals, Inc., Corvallis, Oregon, as Neugene) polymers, and other synthetic sequence-specific nucleic acid polymers providing that the polymers contain nucleobases in a configuration which allows 10 for base pairing and base stacking, such as is found in DNA and RNA. There is no intended distinction in length between the terms "polynucleotide," "oligonucleotide," "nucleic acid" and "nucleic acid molecule," and these terms will be used interchangeably. These terms refer only to the primary structure of the molecule. Thus, these terms 15 include, for example, 3'-deoxy-2',5'-DNA, oligodeoxyribonucleotide N3' P5' phosphoramidates, 2'-O-alkyl-substituted RNA, triple-, double- and single-stranded DNA, as well as triple-, double- and single-stranded RNA, DNA:RNA hybrids, and hybrids 20 between PNAs and DNA or RNA, and also include known types of modifications, for example, labels which are known in the art, methylation, "caps," substitution of one or more of the naturally occurring nucleotides with an analog, internucleotide modifications such as, for example, those with uncharged linkages (e.g., methyl phosphonates, 25 phosphotriesters, phosphoramidates, carbamates, etc.), with negatively charged linkages (e.g., phosphorothioates, phosphorodithioates, etc.), and with positively charged linkages (e.g., aminoalkylphosphoramidates, aminoalkylphosphotriesters), those containing 30 pendant moieties, such as, for example, proteins (including nucleases, toxins, antibodies, signal peptides, poly-L-lysine, etc.), those with intercalators (e.g., acridine, psoralen, etc.), 35 those containing chelators (e.g., metals, radioactive metals, boron, oxidative metals, etc.), those containing alkylators, those with modified linkages (e.g., alpha anomeric nucleic acids, etc.), as well as unmodified forms of the polynucleotide or oligonucleotide. In particular, DNA is deoxyribonucleic acid.

40

45

50

"Polypeptide" and "protein" are used interchangeably herein and include a molecular chain of amino acids linked through peptide bonds. The terms do not refer to a

55

5

12

10

specific length of the product. Thus, "peptides," "oligopeptides," and "proteins" are included within the definition of polypeptide. The terms include post-translational modifications of the polypeptide, for example, glycosylations, acetylations, phosphorylations and the like. In addition, protein fragments, analogs, mutated or variant proteins, fusion proteins and the like are included within the meaning of polypeptide.

15

The term "sugar moiety" includes reference to monosaccharides, disaccharides, polysaccharides, and the like. The term "sugar" includes those moieties which have been modified, e.g., wherein one or more of the hydroxyl groups are replaced with halogen, alkoxy moieties, aliphatic groups, or are functionalized as ethers, amines, or the like.

20

10 Examples of modified sugars include: those which contain a lower alkoxy group in place of a hydroxyl moiety, i.e., α - or β -glycosides such as methyl α -D-glucopyranoside, methyl β -D-glucopyranoside, and the like; those which have been reacted with amines, i.e., N-glycosylamines or N-glycosides such as N-(α -D-glucopyranosyl)methylamine; those containing acylated hydroxyl groups, typically from 1 to 5 lower acyl groups; those 15 containing one or more carboxylic acid groups, e.g., D-gluconic acid or the like; and those containing free amine groups such as D-glucosamine, D-galactosamine, N-acetyl-D-glucosamine or the like. Examples of preferred saccharides are glucose, galactose, fructose, ribose, mannose, arabinose, and xylose. Examples of polysaccharides is dextran and cellulose.

30

20 ~~"One or more sizes of semiconductor nanocrystals":~~ As used herein, the phrase "one or more sizes of semiconductor nanocrystals" is used synonymously with the phrase "one or more particle size distributions of semiconductor nanocrystals". One of ordinary skill in the art will realize that particular sizes of semiconductor nanocrystals are actually obtained as particle size distributions.

40

25 The phrase "associated with" is used herein to indicate items that are physically linked by, for example, covalent chemical bonds, physical forces such van der Waals or hydrophobic interactions, encapsulation, embedding, or the like. The phrase "associated with" also intends maintaining a correspondence between items by other than physical linkage, e.g., through the use of a look-up table or other method of recording the 30 association/correspondence.

50

55

10 As used herein, the term "binding pair" refers first and second molecules that
specifically bind to each other. "Specific binding" of the first member of the binding pair
to the second member of the binding pair in a sample is evidenced by the binding of the
first member to the second member, or vice versa, with greater affinity and specificity
15 than to other components in the sample. The binding between the members of the binding
pair is typically non-covalent. The terms "affinity molecule" and "target analyte" are used
herein to refer to first and second members of a binding pair, respectively.

20 Exemplary binding pairs include any haptenic or antigenic compound in
combination with a corresponding antibody or binding portion or fragment thereof (e.g.,
10 digoxigenin and anti-digoxigenin; mouse immunoglobulin and goat anti-mouse
immunoglobulin) and nonimmunological binding pairs (e.g., biotin-avidin, biotin-
25 strepavidin, hormone [e.g., thyroxine and cortisol]-hormone binding protein, receptor-
receptor agonist or antagonist (e.g., acetylcholine receptor-acetylcholine or an analog
thereof) IgG-protein A, lectin-carbohydrate, enzyme-enzyme cofactor, enzyme-enzyme-
30 inhibitor, and complementary polynucleotide pairs capable of forming nucleic acid
duplexes) and the like.

35 "Optional" or "optionally" means that the subsequently described event or circumstance
may or may not occur, and that the description includes instances where said event or
circumstance occurs and instances where it does not. For example, the phrase "optionally
20 having an overcoating" means that an overcoating may or may not be present and that the
description includes both where there is and where there is not an overcoating, and the like.

40 Recognizing the need to identify and locate specific items or components of
interest, the present invention provides a novel encoding system. In particular, the present
invention utilizes a "barcode" comprising one or more particle size distributions of
25 semiconductor nanocrystals, having characteristic spectral emissions, to either "track" the
location of a particular item of interest or to identify a particular item of interest. The
semiconductor nanocrystals used in the inventive "barcoding" scheme can be tuned to a
45 desired wavelength to produce a characteristic spectral emission by changing the
composition and size of the semiconductor nanocrystal, and additionally, the intensity of
30 the emission at a particular characteristic wavelength can also be varied, thus enabling the

5

14

10

use of binary or higher order encoding schemes. The information encoded by the semiconductor nanocrystals can be spectroscopically decoded, thus providing the location and/or identity of the particular item or component of interest.

15

The ability of the semiconductor nanocrystals to be utilized in the inventive barcode system results from their unique characteristics. Semiconductor nanocrystals have radii that are smaller than the bulk exciton Bohr radius and constitute a class of materials intermediate between molecular and bulk forms of matter. Quantum confinement of both the electron and hole in all three dimensions leads to an increase in the effective band gap of the material with decreasing crystallite size. Consequently, both the optical absorption and emission of semiconductor nanocrystals shift to the blue (higher energies). Upon exposure to a primary light source, each semiconductor nanocrystal distribution is capable of emitting energy in narrow spectral linewidths, as narrow as 25-30 nm, and with a symmetric, nearly Gaussian line shape, thus providing an easy way to identify a particular semiconductor nanocrystal. As one of ordinary skill in the art will realize, the linewidths are dependent on the size heterogeneity, i.e., monodispersity, of the semiconductor nanocrystals in each preparation. Single semiconductor nanocrystal complexes have been observed to have full width at half max (FWHM) as narrow as 12-15 nm. In addition, semiconductor nanocrystal distributions with larger linewidths in the range of 40-60 nm can be readily made and have the same physical characteristics as semiconductor nanocrystals with narrower linewidths.

20

25

30

35

40

45

50

Exemplary materials for use as semiconductor nanocrystals in the present invention include, but are not limited to group II-IV, III-V and group IV semiconductors such as ZnS, ZnSe, ZnTe, CdS, CdSe, CdTe, GaN, GaP, GaAs, GaSb, InP, InAs, InSb, AlS, AlP, AlSb, PbS, PbSe, Ge and Si and ternary and quaternary mixtures thereof. The semiconductor nanocrystals are characterized by their uniform nanometer size. By "nanometer" size, it is meant less than about 150 Angstroms (A), and preferably in the range of 12-150 A.

As discussed above, the selection of the composition of the semiconductor nanocrystal, as well as the size of the semiconductor nanocrystal, affects the characteristic spectral emission wavelength of the semiconductor nanocrystal. Thus, as one of ordinary

55

5

15

10

skill in the art will realize, a particular composition of a semiconductor nanocrystal as listed above will be selected based upon the spectral region being monitored. For example, semiconductor nanocrystals that emit energy in the visible range include, but are not limited to CdS, CdSe, CdTe, ZnSe, ZnTe, GaP, and GaAs. Figure 1 depicts a color 5 photograph of several suspensions of different sizes of ZnS overcoated CdSe semiconductor nanocrystals in hexane illustrating the wide range of colors available for use in the present invention. Semiconductor nanocrystals that emit energy in the near IR range include, but are not limited to, InP, InAs, InSb, PbS, and PbSe. Finally, 10 semiconductor nanocrystals that emit energy in the blue to near-ultraviolet include, but are not limited to ZnS and GaN. For any particular composition selected for the 15 semiconductor nanocrystals to be used in the inventive system, it is possible to tune the emission to a desired wavelength by controlling the size of the particular composition of the semiconductor nanocrystal. In preferred embodiments, 5-20 discrete emissions (five to twenty different size populations or distributions distinguishable from one another) are 20 obtained for any particular composition, although one of ordinary skill in the art will realize that fewer than five emissions and more than twenty emissions could be used depending on the monodispersity of the semiconductor nanocrystal particles. If high 25 information density is required, and thus a greater number of distinct emissions, the nanocrystals are also substantially monodisperse within the broad nanometer range given 30 above (12-150 Å). By monodisperse, as that term is used herein, it means a colloidal system in which the suspended particles have substantially identical size and shape. In 35 preferred embodiments for high information density applications, monodisperse particles deviate less than 10% rms in diameter, and preferably less than 5%. Monodisperse 40 semiconductor nanocrystals have been described in detail in Murray et al. (*J. Am. Chem. Soc.*, 1993, 115, 8706), and in the thesis of Christopher Murray, "Synthesis and 45 Characterization of II-VI Quantum Dots and Their Assembly into 3-D Quantum Dot Superlattices", Massachusetts Institute of Technology, September, 1995. One of ordinary 50 skill in the art will also realize that the number of discrete emissions that can be distinctly observed for a given composition depends not only upon the monodispersity of the 55 particles, but also on the deconvolution techniques employed. Semiconductor

55

5

16

10

nanocrystals, unlike dye molecules, can be easily modeled as Gaussians and therefore are more easily and more accurately deconvoluted.

15

However, for some applications high information density will not be required and it may be more economically attractive to use more polydisperse particles. Thus, for 5 applications that do not require high information density, the linewidth of the emission may be in the range of 40-60 nm.

20

In addition to the ability to tune the emission energy by controlling the size of the particular semiconductor nanocrystal, the intensities of that particular emission observed at a specific wavelength are also capable of being varied, thus increasing the potential 10 information density provided by the semiconductor nanocrystal "barcode" system. In preferred embodiments, 2-15 different intensities may be achieved for a particular 25 emission at a desired wavelength, however, one of ordinary skill in the art will realize that more than fifteen different intensities may be achieved, depending upon the particular application of the inventive identification units. For the purposes of the present invention, 30 15 different intensities may be achieved by varying the concentrations of the particular size semiconductor nanocrystal attached to, embedded within or associated with an item or component of interest.

35

In a particularly preferred embodiment, the surface of the semiconductor nanocrystal is also modified to enhance the efficiency of the emissions, by adding an 20 overcoating layer to the semiconductor nanocrystal. The overcoating layer is particularly preferred because at the surface of the semiconductor nanocrystal, surface defects can 40 result in traps for electron or holes that degrade the electrical and optical properties of the semiconductor nanocrystal. An insulating layer at the surface of the semiconductor nanocrystal provides an atomically abrupt jump in the chemical potential at the interface 25 that eliminates energy states that can serve as traps for the electrons and holes. This 45 results in higher efficiency in the luminescent process.

50

Suitable materials for the overcoating layer include semiconductors having a higher band gap energy than the semiconductor nanocrystal. In addition to having a band gap energy greater than the semiconductor nanocrystals, suitable materials for the 30 overcoating layer should have good conduction and valence band offset with respect to the

55

5

17

10

semiconductor nanocrystal. Thus, the conduction band is desirably higher and the valence band is desirably lower than those of the semiconductor nanocrystal. For semiconductor nanocrystals that emit energy in the visible (e.g., CdS, CdSe, CdTe, ZnSe, ZnTe, GaP, GaAs) or near IR (e.g., InP, InAs, InSb, PbS, PbSe), a material that has a band gap energy in the ultraviolet regions may be used. Exemplary materials include ZnS, GaN, and magnesium chalcogenides, e.g., MgS, MgSe, and MgTe. For semiconductor nanocrystals that emit in the near IR, materials having a band gap energy in the visible, such as CdS or CdSe, may also be used. The overcoating layer may include as many as eight monolayers of the semiconductor material. The preparation of a coated semiconductor nanocrystal may be found in U.S.S.N. 08/969,302, filed November 13, 1997 and entitled "Highly Luminescent Color-Selective Materials", and Dabbousi et al., (*J. Phys. Chem. B*, 1997, 101, 9463) and Kuno et al., (*J. Phys. Chem.*, 1997, 101, 9869).

15

20

25

30

35

40

45

50

After selection of a particular collection of semiconductor nanocrystal composition and sizes as discussed above to associate with an item of interest, the semiconductor nanocrystals can be attached to, embedded within or associated with that particular item of interest. As one of ordinary skill in the art will realize, the item of interest must be sufficiently reactive with the surface of the semiconductor nanocrystal, or must be sufficiently compatible with the semiconductor nanocrystal.

Most semiconductor nanocrystals are prepared in coordinating solvent, such as trioctylphosphine oxide (TOPO) and trioctyl phosphine (TOP) resulting in the formation of a passivating organic layer on the dot surface comprised of the organic solvent. This layer is present on semiconductor nanocrystals containing an overcoating and those that do not contain an overcoating. Thus, either of these classes of passivated semiconductor nanocrystals are readily soluble in organic solvents, such as toluene, chloroform and hexane. As one of ordinary skill in the art will realize, these functional moieties may be readily displaced or modified to provide an outer coating that renders the semiconductor nanocrystals suitable for use as the identification units of the present invention. Furthermore, based upon the desired application, a portion of the semiconductor nanocrystal functionality, or the entire surface of the semiconductor nanocrystal functionality may be modified by a displacement reaction, based upon the desired

55

5

18

10 application of the inventive identification units. Figure 2 depicts general displacement reactions of certain functional moieties to provide a semiconductor nanocrystals with modified functionalities for use in the inventive method. Figure 2 also depicts the ability to displace a specific percentage of moieties on the surface of the semiconductor
15 5 nanocrystals. For example, reaction A, depicts the partial displacement of moiety X by moiety Y, whereas reaction B depicts the complete displacement of moiety X by moiety Y for a semiconductor nanocrystal having no overcoating layer. Reactions C and D depict the partial and complete displacement reactions for overcoated semiconductor
20 10 nanocrystals, respectively. In general, moieties such as TOPO and TOP, as well as other
25 15 moieties may be readily displaced and replaced with other functional moieties, including, but not limited to carboxylic acids, amines, aldehydes, and styrene to name a few. One of ordinary skill in the art will realize that factors relevant to the success of a particular
30 20 displacement reaction include the concentration of the replacement moiety, temperature and reactivity. Thus, for the purposes of the present invention, any functional moiety may
35 25 be utilized that is capable of displacing an existing functional moiety to provide a semiconductor nanocrystal with a modified functionality for a specific use of the
40 30 identification units of the present invention.

The ability to utilize a general displacement reaction to modify selectively the
45 35 surface functionality of the semiconductor nanocrystals enables functionalization for
50 40 20 specific uses of the inventive identification units: In one particularly preferred
embodiment, water soluble semiconductor nanocrystals are provided for use in aqueous
environments. In the case of water-soluble semiconductor nanocrystals, the outer layer
includes a compound having at least one linking moiety that attaches to the surface of the
55 45 particle and that terminates in at least one hydrophilic moiety. The linking and
25 50 hydrophilic moieties are spanned by a hydrophobic region sufficient to prevent charge
transfer across the region. The hydrophobic region also provides a "pseudo-hydrophobic"
environment for the nanocrystal and thereby shields it from aqueous surroundings. A
detailed description of methods for making water soluble semiconductor nanocrystals may
be found in the application entitled "Water Soluble Luminescent Nanocrystals" filed the
30 55 same day herewith. In preferred embodiments, the hydrophilic moiety may be a polar or

55

5

19

10

charged (positive or negative) group. The polarity or charge of the group provides the necessary hydrophilic interactions with water to provide stable solutions or suspensions of the semiconductor nanocrystal. Exemplary hydrophilic groups include polar groups such as hydroxides (-OH), amines, polyethers, such as polyethylene glycol and the like, as well as charged groups, such as carboxylates (-CO²⁻), sulfonates (SO³⁻), phosphates (-PO₄²⁻ and -PO₃²⁻), nitrates, ammonium salts (-NH⁴⁺), and the like.

15

In another particularly preferred embodiment, a displacement reaction may be employed to modify the semiconductor nanocrystal to improve the solubility in a particular organic solvent. For example, if it is desired to associate the semiconductor 10 nanocrystals with a particular solvent or liquid, such as pyridine, the surface can be specifically modified with pyridine or pyridine-like moieties to ensure solvation.

25

In yet another particularly preferred embodiment, the surface layer is modified by displacement to render the semiconductor nanocrystal reactive for a particular coupling reaction. For example, displacement of TOPO moieties with a group containing a 15 carboxylic acid moiety enables the reaction of the modified semiconductor nanocrystals with amine containing moieties (commonly found on solid support units) to provide an amide linkage.

30

Likewise, the surface of the semiconductor nanocrystal can also be modified to 35 create a surface on the semiconductor nanocrystal similar to an object that the semiconductor nanocrystal will be associated with. For example, the semiconductor 20 nanocrystal surface can be modified using a displacement reaction to create styrene or acrylate moieties, thus enabling the incorporation of the semiconductor nanocrystals into 40 polystyrene, polyacrylate or other polymers such as polymer, such as polyimide, polyacrylamide, polyethylene, polyvinyl, poly-diacetylene, polyphenylene-vinylene, 25 polypeptide, polysaccharide, polysulfone, polypyrrrole, polyimidazole, polythiophene, polyether, epoxies, silica glass, silica gel, siloxane, polyphosphate, hydrogel, agarose, 45 cellulose, and the like..

40

After selection of the composition of semiconductor nanocrystal for the desired 50 range of spectral emission and selection of a desired surface functionalization compatible 30 with the system of interest, it may also be desirable to select the minimum number of

55

5

20

10

semiconductor nanocrystals needed to observe a distinct and unique spectral emission of sufficient intensity for spectral identification. Selection criteria important in determining the minimum number of semiconductor nanocrystals needed to observe a distinct and unique spectral emission of sufficient intensity include providing a sufficient number of 5 semiconductor nanocrystals that are bright (i.e., that emit light versus those that are dark) and providing a sufficient number of semiconductor nanocrystals to average out over the blinking effect observed in single semiconductor nanocrystal emissions (M. Nirmal et al., *Nature*, 1996, 383, 802). In one particularly preferred embodiment, at least eight 15 semiconductor nanocrystals of a particular composition and particle size distribution are provided. For example, if a "barcode" were provided that utilized three different particle 20 size distributions of a particular composition, it would be most desirable to utilize eight of each of the three different particle size distributions of a semiconductor nanocrystal, in order to observe sufficiently intense spectral emissions from each to provide reliable 25 information regarding the location or identity of a particular item or matter of interest.

30 One of ordinary skill in the art will realize, however, that fewer than eight semiconductor nanocrystals of a particular composition and particle size distribution could be utilized provided that a unique spectral emission of sufficient intensity is observed, as determined by the selection criteria set forth above.

35

As discussed previously, the ability of the semiconductor nanocrystals to produce 40 discrete optical transitions, along with the ability to vary the intensity of these optical transitions, enables the development of a versatile and dense encoding scheme. The characteristic emissions produced by one or more sizes of semiconductor nanocrystals attached to, associated with, or embedded within a particular support or matter enables the 45 identification of the item or composition of interest and/or its location. For example, by providing N sizes of semiconductor nanocrystals (each having a discrete optical transition), each having M distinguishable states resulting from the absence of the semiconductor nanocrystal, or from different intensities resulting from a particular 50 discrete optical transition, M^N different states can be uniquely defined. In the case of $M = 2$ where the two states could be the presence or absence of the semiconductor nanocrystal, 55 the encoding scheme would thus be defined by a base 2 or binary code. In the case of M

55

5

21

10

= 3 where the three states could be the presence of a semiconductor nanocrystal at two distinguishable intensities or its absence, the encoding scheme would be defined by a base 3 code. Herein, such base M codes where $M > 2$ are termed higher order codes. The advantage of higher order codes over a binary order code is that fewer identifiers are required to encode the same quantity of information.

15

As one of ordinary skill in the art will realize, the ability to develop a higher order encoding system is dependent upon the number of different intensities capable of detection by both the hardware and the software utilized in the decoding system. In particularly preferred embodiments, each discrete emission or color, is capable of being detectable at two to twenty different intensities. In a particularly preferred embodiment wherein ten different intensities are available, it is possible to employ a base 11 code comprising the absence of the semiconductor nanocrystal, or the detection of the semiconductor nanocrystal at 10 different intensities.

20

Clearly, the advantages of the semiconductor nanocrystals, namely the ability to observe discrete optical transitions at a plurality of intensities, provides a powerful and dense encoding scheme that can be employed in a variety of disciplines. In general, one or more semiconductor nanocrystals may act as a barcode, wherein each of the one or more semiconductor nanocrystals produces a distinct emissions spectrum. These characteristic emissions can be observed as colors, as shown in Figure 1, if in the visible region of the spectrum, or may also be decoded to provide information about the particular wavelength at which the discrete transition is observed. Likewise, for semiconductor nanocrystals producing emissions in the infrared or ultraviolet regions, the characteristic wavelengths that the discrete optical transitions occur at provide information about the identity of the particular semiconductor nanocrystal, and hence about the identity of or location of the item or matter of interest.

25

30

An example of a specific system for automated detection that could be employed for use in the present invention includes, but is not limited to, an imaging scheme comprising an excitation source, a monochromator (or any device capable of spectrally resolving the image, or a set of narrow band filters) and a detector array. In one 40 embodiment, the apparatus would consist of a blue or UV source of light, of a wavelength 45

50

55

30

5

22

10

shorter than that of the luminescence detected. This could be a broadband UV light source, such as a deuterium lamp with a filter in front; the output of a white light source such as a xenon lamp or a deuterium lamp after passing through a monochromator to extract out the desired wavelengths; or any of a number of cw gas lasers, including but not limited to any of the Argon Ion laser lines (457, 488, 514, etc. nm), a HeCd laser; solid state diode lasers in the blue such as GaN and GaAs (doubled) based lasers or the doubled or tripled output of YAG or YLF based lasers; or any of the pulsed lasers with output in the blue, to name a few. The luminescence from the dots would be passed through an imaging subtracting double monochromator (or two single monochromators with the 10 second one reversed from the first), for example, consisting of two gratings or prisms and a slit between the two gratings or prisms. The monochromators or gratings or prisms can also be replaced with a computer controlled color filter wheel where each filter is a narrow band filter centered at the wavelength of emission of one of the dots. The monochromator assembly has more flexibility because any color can be chosen as the 15 center wavelength. Furthermore, a CCD camera or some other two dimensional detector records the images, and software color codes that image to the wavelength chosen above. The system then moves the gratings to a new color and repeats the process. As a result of this process, a set of images of the same spatial region is obtained and each is color-coded to a particular wavelength that is needed to analyze the data rapidly.

20

20 In another preferred embodiment, the apparatus is a scanning system as opposed to the above imaging scheme. In a scanning scheme, the sample to be analyzed is scanned with respect to a microscope objective. The luminescence is put through a single monochromator or a grating or prism to spectrally resolve the colors. The detector is a 40 diode array that then records the colors that are emitted at a particular spatial position.

35

25 The software then ultimately recreates the scanned image and decodes it.

45

More particularly, specific preferred embodiments for uses of the inventive encoding system are described with reference to the following examples. These examples are provided only for the purposes of illustration and are not intended to limit the scope of the present invention.

50

30

55

10

Applications to fluid dynamics and microfluidics

15

In one particularly preferred embodiment, the inventive system can be utilized to track or trace the location of a component of interest. For example, fluid dynamics involves generally monitoring the interaction between different fluid components, and thus the location of individual molecules of the desired fluid provides valuable information about the effectiveness of and the degree of interaction between separate components, specifically the controlled movement and mixing of components. In the method of the present invention, one of ordinary skill in the art will realize that the semiconductor nanocrystals can be appropriately functionalized to facilitate interaction with the desired component of interest (so that the semiconductor nanocrystals are compatible with the fluid they are intended to act as tracers for), as discussed in detail earlier, and subsequent mixing of the individual components can be effected. In but one example, if the interaction between two fluids having different characteristics, such as pyridine and dimethylsulfoxide, is being studied, the surface of the semiconductor nanocrystals can be modified with pyridine or dimethylsulfoxide moieties to ensure association of or compatibility of a particular size distribution of semiconductor nanocrystals with the appropriate fluid. Because each the semiconductor nanocrystals are specifically associated with a particular component, it is then possible to take a photograph of the reaction mixture with a ultraviolet lamp and, based upon the discrete optical emissions produced from the semiconductor nanocrystals, gain information about the degree of interaction of the individual components. Figure 3 depicts a general method for fluid dynamics, wherein two streams of fluid (10) and (20), represented by X and Y in Figure 3, are introduced into a reaction chamber (30) and the mixing of the fluids is monitored by taking a "picture" at a given time with an excitation source to observe the position of the semiconductor nanocrystals associated with the particular fluid. Figure 3B depicts an enlargement of the reaction chamber (30) and shows the association of the semiconductor nanocrystals (40) with a particular fluid of interest (10). One of ordinary skill in the art will realize that the ability of the semiconductor nanocrystals to produce discrete transitions enables the mixing of N components, where N represents the number of discrete transitions.

20

25

30

35

40

45

50

55

5

24

10

One particularly preferred application for this system for location identification described above is the monitoring of microfluidic molecular systems (MicroFlumes). These microfluidic systems perform multiple reaction and analysis techniques in one microinstrument for specificity and validation, they are completely automated, they 5 contain multiple parallel reaction paths (as opposed to the sequential analysis required today) and provide the capability for hundreds of operations to be performed without manual intervention. (See <http://web-ext2.darpa.mil/eto/mFlumes/index.html>)

20

The semiconductor nanocrystal semiconductor nanocrystals can be used as in the general method described above, where each semiconductor nanocrystal or combination 10 thereof can be associated with or attached to a specific component of interest and upon mixing of the various components, and providing a primary light source, can provide information about the degree and type of interaction between the different components. 25 One of ordinary skill in the art will realize that the inventive encoding system is not limited to the fluid dynamics applications described above; rather the inventive system is 15 capable of being utilized in any system where the tracking of the location of a component or item, such as a gas, liquid, solid, or consumer item (such as dry-cleaned clothing) is desired.

35

Identification of an object

40

20 The system of the present invention can also be utilized to identify specific objects including, but not limited to, jewelry, paper, biomolecules such as DNA, vehicles and identification cards. For example, the semiconductor nanocrystals can be appropriately 25 functionalized for incorporation into or attachment to the surface of the object of interest, as discussed above, and as shown in Figure 4. Figure 4A depicts the incorporation of the semiconductor nanocrystals into an item of interest (50), wherein the surface of 45 semiconductor nanocrystal has been modified to enable incorporation into the item of interest. Figure 4B depicts the coating of a semiconductor nanocrystal composition (80) into an item of interest (90), wherein the surface of the semiconductor nanocrystal (70) is modified to interact with the composition medium X (60). In but one example, the 50 semiconductor nanocrystal surface may be functionalized with a specific percentage of

55

5

25

10

amine moieties, thus enabling incorporation into paper, which is comprised of carbohydrate moieties. In other embodiments, the semiconductor nanocrystals may be appropriately functionalized with moieties such as styrene or acrylate to enable incorporation into polymers. The polymers containing the identification units can then be 15 coated onto, or incorporated within specific items such as identification cards. The ease 5 with which the semiconductor nanocrystals can be incorporated into the item and the fact that the semiconductor nanocrystal based "barcode" is invisible, provides a useful system 20 for labeling objects. The ability of the semiconductor nanocrystal "barcode" system to encode large amounts of information, and thus large numbers of items, provides an 10 advantage over existing barcode or microparticle systems discussed previously. The 25 identification of the item of interest from a collection of items can be effected by providing a primary light source and correlating the spectral emissions to a collection of 30 semiconductor nanocrystals that encode a particular item of interest. In another 35 particularly preferred embodiment, the present system may be utilized to keep track of the 15 identity of biomolecules, such as DNA sequences, while they are subjected to reaction processes and chemical manipulations. The biomolecules, or DNA sequences, could be "tagged" themselves, or, alternatively, the biomolecules could be attached to a support, wherein the support is "tagged" with one or more sizes of semiconductor nanocrystals 20 encoding the identity of the DNA sequence.

20

Encoding combinatorial libraries

In another particularly preferred embodiment, the inventive semiconductor 40 nanocrystals may also be used to identify a particular compound in a library of compounds by encoding a particular reaction sequence employed for each of the 45 25 compounds in the synthesis of complex combinatorial libraries, and thus acting as an identifier. Because of the desirability for the production of large numbers of complex compounds, particularly using a split and pool method, the development of encoding techniques to identify each compound of interest has become important. Because of the 50 small quantity of final product or compound produced from such methods, identifying

55

5

26

10

these products would generally not be feasible. However, by associating each stage or combination of stages of the serial synthesis with an identifier which defines the choice of variables such as reactant, reagent, reaction conditions, or a combination of these, one can use the identifiers to define the reaction history of each definable and separable substrate.

15

5 The spectral analysis of the semiconductor nanocrystals allows for ready identification of the reaction history. For example, one can determine a characteristic of a product of a synthesis, usually a chemical or biological characteristic by various screening techniques, and then identify the reaction history and thereby the structure of that product, which has 20 the desired characteristic, by virtue of the semiconductor nanocrystal "barcode" associated 10 with the product.

25

The use of the instant multiple identification system avoids the necessity of carrying out a complicated cosynthesis which reduces yields and requires multiple protecting groups, and avoids the necessity of using sequenceable tags which are necessarily chemically labile. Both the necessity of multiple protecting groups and the 15 intrinsic instability of all known sequenceable tagging molecules (i.e. nucleic acid or peptide oligomers) severely limit the chemistry which may be used in the synthesis of the library element or ligand. Additionally, the present system avoids the need to cleave the tags from the solid support for analysis.

35

Moreover, the advantage of providing a distinct and non-overlapping resonance, 20 capable of detection at different intensities, enables the use of a binary encoding system or higher. For example, the absence or presence of a particular size semiconductor 40 nanocrystal could be used in a binary system. However, the use of different intensities, of the same color enables the use of a higher order encoding system, each color intensity encoding a particular characteristic.

45

25 According to the method of the present invention, the products to be encoded include, but are not limited to biomolecules (such as peptides and oligonucleotides, organic compounds, and inorganic compounds and catalysts resulting from combinatorial synthesis. Exemplary combinatorial libraries that can be synthesized using the present 50 encoding method include, but are not limited to peptide libraries, peptidomimetics, 30 carbohydrates, organometallic catalysts and small molecule libraries (For examples see,

55

5

27

10

Kahne, D. *Curr. Opin. Chem. Biol.*, 1997, 1, 130; Hruby et al., *Curr. Opin. Chem. Biol.*, 1997, 1, 114; Gravert et al., *Curr. Opin. Chem. Biol.*, 1997, 1, 107).

15

In a particularly preferred embodiment, a solid phase synthesis technique such as split and pool synthesis is utilized, in which the desired scaffold structures are attached to the solid phase directly or through a linking unit, as discussed above. Advantages of solid phase techniques include the ability to conduct multi-step reactions more easily and the ability to drive reactions to completion because excess reagents can be utilized and the unreacted reagent washed away. Perhaps one of the most significant advantages of solid phase synthesis is the ability to use a technique called "split and pool", in addition to the

20

parallel synthesis technique, developed by Furka. (Furka et al., *Abstr. 14th Int. Congr. Biochem.*, Prague, Czechoslovakia, 1988, 5, 47; Furka et al., *Int. J. Pept. Protein Res.*

25

1991, 37, 487; Sebestyen et al., *Bioorg. Med. Chem. Lett.*, 1993, 3, 413.) In this technique, a mixture of related compounds can be made in the same reaction vessel, thus substantially reducing the number of containers required for the synthesis of very large

30

15 libraries, such as those containing as many as or more than one million library members.

As an example, the solid support scaffolds can be divided into n vessels, where n represents the number species of reagent A to be reacted with the scaffold structures.

35

After reaction, the contents from n vessels are combined and then split into m vessels, where m represents the number of species of reagent B to be reacted with the scaffold 20 structures. This procedure is repeated until the desired number of reagents is reacted with the scaffold structures to yield the inventive library.

40

The semiconductor nanocrystals of the present invention can be readily attached to a solid support. A solid support, for the purposes of this invention, is defined as an insoluble material to which compounds are attached during a synthesis sequence. The use 25 of a solid support is advantageous for the synthesis of libraries because the isolation of support-bound reaction products can be accomplished simply by washing away reagents from the support-bound material and therefore the reaction can be driven to completion by the use of excess reagents. A solid support can be any material that is an insoluble matrix and can have a rigid or semi-rigid surface. Exemplary solid supports include but are not 30 limited to pellets, disks, capillaries, hollow fibers, needles, pins, solid fibers, cellulose

50

55

10

beads, pore-glass beads, silica gels, polystyrene beads optionally cross-linked with divinylbenzene, grafted co-poly beads, poly-acrylamide beads, latex beads, dimethylacrylamide beads optionally crosslinked with N-N'-bis-acryloylenediamine, and glass particles coated with a hydrophobic polymer. In one particularly preferred embodiment, a Tentagel amino resin, a composite of 1) a polystyrene bead crosslinked with a divinylbenzene and 2) PEG (polyethylene glycol), is employed for use in the present invention. The semiconductor nanocrystals of the present invention can readily be functionalized with styrene and thus can be incorporated into Tentagel beads, or the semiconductor nanocrystals may be functionalized with a carboxylate moiety and can be readily attached to the Tentagel support having an amine moiety through an amide linkage. Tentagel is a particularly useful solid support because it provides a versatile support for use in on-bead or off-bead assays, and it also undergoes excellent swelling in solvents ranging from toluene to water.

15

20

25

30

35

40

45

50

55

The semiconductor nanocrystals therefore identify each reaction stage that an individual solid support has experienced, and records the step in the particular synthesis series, as shown in Figure 5. Figure 5 depicts the attachment of three different reagents A, B, and C (120) to a solid support, and the attachment of the identification unit (140) to the solid support (100) via a linkage (90). The supports are then pooled together (130) and split for reaction with reagents D, E, and F. Attachment of appropriate identification units for each of these reagents enables the encoding of this particular reaction stage as observed previously for reagents A, B, and C. In this particular embodiment, the tags may be attached to all (or most) of the solid supports immediately before, during, or immediately after the reaction stage, depending on the particular chemistry used in a given reaction sequence.

In another preferred embodiment, the beads can be labeled with the semiconductor nanocrystals prior to reaction of the beads with any reagents, and as the beads are split in the split and pool process, the beads are read before being added to a new (split stage) container to keep track of the particular reaction at that particular stage in the synthesis.

Once the synthesis is complete, the library of compounds can then be screened for biological activity and the supports having a compound of interest can then be analyzed

5

29

10

directly (on-bead analysis) to provide information about the reaction stages and history of the synthesis.

15

Although the method described above is with reference to split and pool combinatorial techniques, one of ordinary skill in the art will realize that the present 5 encoding scheme is not limited to split and pool methods; rather the inventive encoding scheme can be utilized in any combinatorial or other reaction scheme such as parallel synthesis, or synthesis of compounds on an array, to name a few.

20

Genomics Applications:

25

10 In another particularly preferred embodiment of the present invention, the inventive system can be utilized to gain information about genetic information from oligonucleotide fragments. In general, it has been desirable to understand genetic variation and its consequences on biological function, and in order to do this, an enormous 15 comparative sequence analysis must be carried out. Because each DNA strand has the capacity to recognize a uniquely complementary sequence through base pairing, the process of recognition, or hybridization, is highly parallel, as every nucleotide in a large 30 sequence can in principle be queried at the same time.

35

DNA chip technology has been an important tool for genomics applications. Single nucleotide polymorphisms (SNPs) are the most frequently observed class of 20 variations in the human genome. Detecting the differences between alleles of genes is a significant goal of medical research into genetic diseases and disorders. (For example, sickle cell anemia, colon cancer, BRCA1). Current technology has allowed for large scale 40 screening of DNA sequences for mutations in the sequence. This technology involves the creation of DNA "chips" that contain high-density arrays of DNA sequences (e.g. STSs) 25 covalently bound at specific locations on a surface (glass). A set of four oligonucleotides of identical sequence except for a single base alteration (A, G, T, or C) near the center is 45 used to compare two alleles of a gene. Single nucleotide differences between alleles at the position complementary to altered sites in the set of four oligos will allow one oligonucleotide to hybridize preferentially over the other three. Detecting which 50 oligonucleotide hybridizes to the sample DNA will then identify the sequence of the 30

55

5

30

10

polymorphism. By creating sets of these four oligos that are shifted over by one nucleotide each, a researcher can scan a large number of basepairs for single nucleotide polymorphisms.

15

The system of the present invention, in contrast to fluorescently labeled probes used in the existing methods, is capable of not only acting as a probe for identification of a desired sequence, but is also capable of encoding information about the sequence itself. Because the inventive identification system is capable of providing both a probe and identifier, ordered arrays are not necessary for accessing genetic information, although the inventive system can still be used in traditional arrays. Instead, a collection of beads, for example, can be assembled with the desired labeled DNA fragments, wherein said beads are also encoded with information about the particular sequence. Upon binding, the oligonucleotide that hybridizes to the sample DNA can be detected by scanning the sample to identify the semiconductor nanocrystal labeled probe, while at the same time the sequence information can then be decoded by analyzing the semiconductor nanocrystal 15 "barcode".

20

25

30

35

40

45

50

55

Claims

5

10

15

20

25

30

35

40

45

50

55

5

31

10

We claim:

15 1. A composition comprising of one or more populations of member
5 semiconductor nanocrystals, wherein each population has a distinct characteristic spectral
emission.

20

2. A composition comprising:

(a) a support; and

10 (b) the composition of one or more populations of member semiconductor
nanocrystals of claim 1 associated with the support,
25 to provide a support-nanocrystal conjugate.

25

3. A composition comprising:

15 (a) a composition comprising of one or more populations of member
semiconductor nanocrystals, wherein each population has a distinct characteristic spectral
emission; and(b) an item of interest associated with the composition,
35 to provide a nanocrystal-item of interest conjugate.

20

4. The composition of claim 2, further comprising a item of interest
associated with the support-nanocrystal conjugate.

40

5. The composition of claim 1, 2, 3 or 4, wherein the characteristic spectral
emission is a wavelength of emitted light, an intensity of emitted light, or both an intensity
25 of emitted light and a wavelength of emitted light.

45

6. The composition of claim 2, 3 or 4, wherein the association is selected
from the group consisting of covalent, hydrophobic, van der Waals forces, adsorption, and
interaction between first and second members of a binding pair.

50

30

55

5

32

10

7. The composition of claim 6, wherein the association is the interaction between first and second members of a binding pair.

15

8. The composition of claim 7, wherein the first member of the binding pair comprises an antibody or binding portion or fragment thereof, an antigen, avidin, streptavidin, or biotin.

20

9. The composition of claim 2 or 4, wherein the support comprises cellulose, polystyrene, polyacrylamide, silica gels, polystyrene cross-linked with divinylbenzene, latex, dimethylacrylamide, dimethylacrylamide cross-linked with N,N'-bis-acryloyl ethylene diamine, low molecular weight non-cross-linked polystyrene, polyacrylate, polyimide, polyethylene, polyvinyl, poly-diacetylene, polyphenylene-vinylene, polypeptide, polysaccharide, polysulfone, polypyrrole, polyimidazole, polythiophene, polyether, epoxies, siloxane, polyphosphate, hydrogel, agarose, silica, glass, grafted co-polymers, pore-glass and glass coated with a hydrophobic polymer.

30

10. The composition of claim 2 or 4, wherein the support is in the form of a bead, a pellet, a disk, a capillary, a hollow fiber, a needle or a solid fiber.

35

20 11. The composition of claim 3 or 4, wherein said item of interest is selected from the group consisting of a consumer product, an identification tag, a security tag, a chemical compound, a biomolecule, a fluid and a solid.

40

12. The composition of claim 3 or 4, wherein the item of interest is an oligonucleotide, a polypeptide, or a sugar moiety.

45

13. The composition of claim 1, 2, 3 or 4, wherein each nanocrystal member of each population of the collection comprises:

50

30 a core comprising a first semiconductor material; and a shell layer overcoating the core, the shell comprising a second semiconductor

55

5

33

10

material having a band gap greater than that of the core,
wherein the first semiconductor material and the second semiconductor material
are the same or different.

15

5 14. The composition of claim 13, wherein the core is a Group II-VI, Group III-V or
Group IV semiconductor.

20

15. The composition of claim 13, wherein the core comprises CdS, CdSe,
CdTe, ZnS, ZnSe, ZnTe, MgTe, GaAs, GaP, GaSb, GaN, HgS, HgSe, HgTe, InAs, InP,
10 InSb, InN, AlAs, AlP, AlSb, AlS, PbS, PbSe, Ge, Si, an alloy thereof, or a mixture
thereof.

25

16. The composition of claim 15, wherein the shell comprises ZnO, ZnS,
ZnSe, ZnTe, CdO, CdS, CdSe, CdTe, MgS, MgSe, GaAs, GaN, GaP, GaAs, GaSb, HgO,
15 HgS, HgSe, HgTe, InAs, InN, InP, InSb, AlAs, AlN, AlP, AlSb, an alloy thereof, or a
mixture thereof.

30

35

17. The composition of claim 13, wherein the core is CdSe and the shell is
ZnS.

40

20 18. The composition of claim 13, wherein the core is a member of a monodisperse
particle population.

45

19. The composition of claim 18, wherein the monodisperse particle population is
25 characterized in that when irradiated the population emits light in a spectral range of about
40-60 nm full width at half maximum (FWHM).

50

20. The composition of claim 19, wherein the monodisperse particle population is
characterized in that when irradiated the population emits light in a spectral range of about
30 12-15 nm full width at half maximum (FWHM).

55

5

34

10

21. The composition of claim 18, wherein the monodisperse particle population is characterized in that it exhibits no more than about a 10% rms deviation in the diameter of the core.

15

5

22. The composition of claim 21, wherein the monodisperse particle population is characterized in that it exhibits no more than about 5% rms deviation in the diameter of the core.

20

10

23. A method for identifying an item of interest, comprising:

(a) providing the composition of claim 1 or 2;

25 (b) associating the composition with the item of interest to provide an encoded item of interest;

(c) subjecting the encoded item of interest to a light source to obtain the 15 characteristic spectral emission; and

30 (d) correlating said spectral emission with the identity of said item of interest.

24. A library of compounds, wherein each compound in the library is bound to 35 an individual support, each support having associated therewith one or more populations 20 of semiconductor nanocrystals, each population having a distinct characteristic spectral emissions.

40

25. The library of claim 24, wherein each nanocrystal member comprises:

a core comprising a first semiconductor material; and

25 a shell layer overcoating the core, the shell comprising a second semiconductor material having a band gap greater than that of the core,

45 wherein the first semiconductor material and the second semiconductor material are the same or different.

50

30 26. The library of claim 25, wherein the characteristic spectral emission is a

55

5

35

10

wavelength of emitted light, an intensity of emitted light, or both a wavelength and an intensity of emitted light.

15

27. A method for identifying a compound having a characteristic of interest comprising:

20

(a) providing a library of member compounds, wherein each member of said library of compounds is attached to a support, and wherein each support also has attached thereto or embedded therein one or more populations of semiconductor nanocrystals each population having distinct characteristic spectral emissions;

25

(b) testing each member of said library of compounds to identify compounds having a characteristic of interest;

30

(c) subjecting each support to a light source to obtain the characteristic spectral emission; and

(d) correlating the spectral emission with the identity of the compound having the characteristic of interest.

35

28. A method for identifying a molecule having a characteristic of interest comprising:

40

providing a first library of one or more member molecules, wherein each member of said first library is attached to a first support having attached thereto or embedded therein one or more first populations of semiconductor nanocrystals, each first population having a distinct characteristic first spectral emission;

45

providing a second library of one or more member molecules, wherein each member of said second library is attached to a second support having attached thereto or embedded therein one or more second populations of semiconductor nanocrystals, each second population having a distinct characteristic second spectral emission, and wherein the second spectral emission is distinct from the first spectral emission;

50

contacting said first library of molecules with said second library of molecules observing the first and second spectral emissions, wherein said first and second spectral emissions provide information about which of the molecules from the second

5

36

10

library of molecules are associated with said first library of molecules, and provides information about the identity of the molecule from said first library of molecules.

15

29. The method of claim 28, wherein the first library of molecules and the second library of molecules are both proteins, oligonucleotides or sugar moieties.

20

30. The method of claim 28, wherein the first support is a first bead and second support is a second bead.

25

30

35

40

45

50

55

BEST AVAILABLE COPY

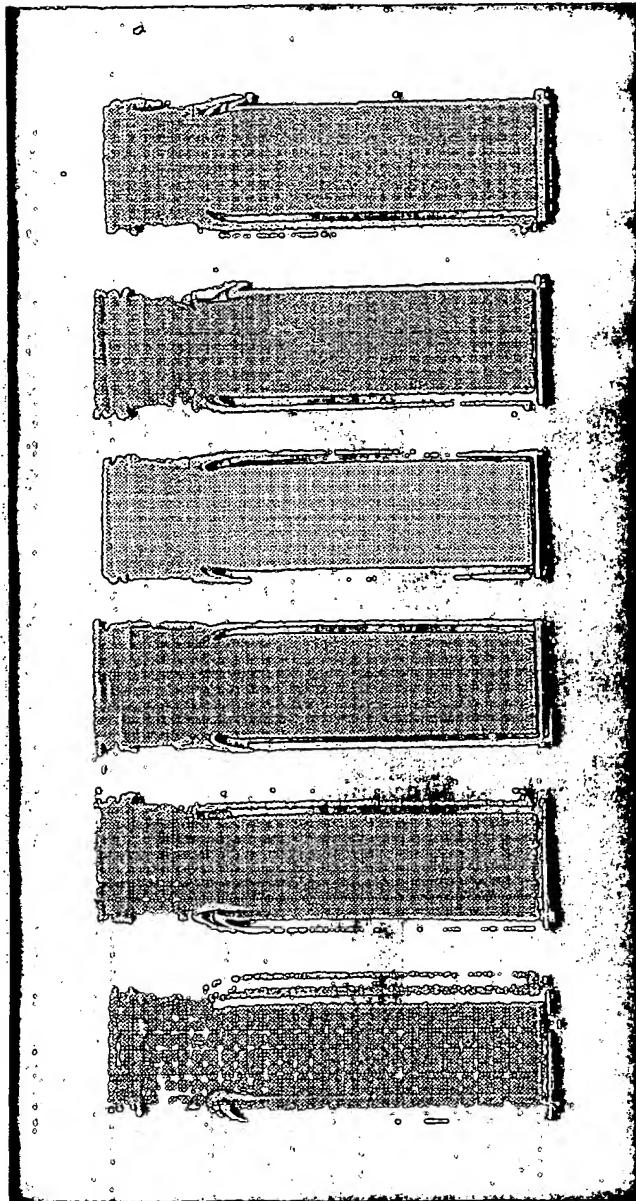
WO 00/17103

1/5

PCT/US99/21373

Fig. 1

A B C D E F



© FELICE FRANKEL 1998

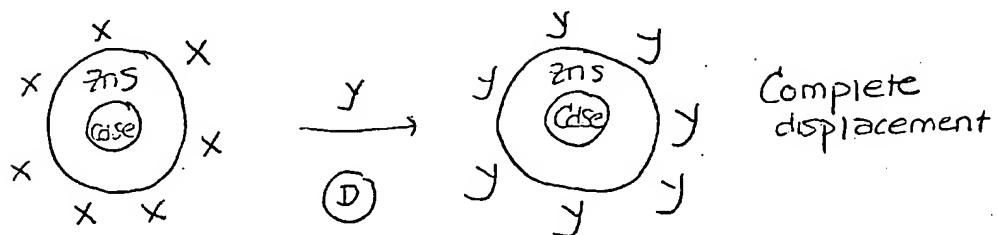
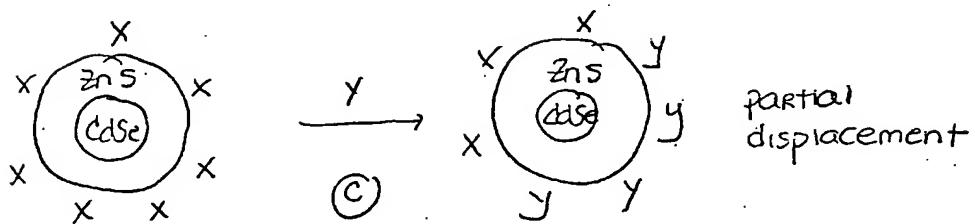
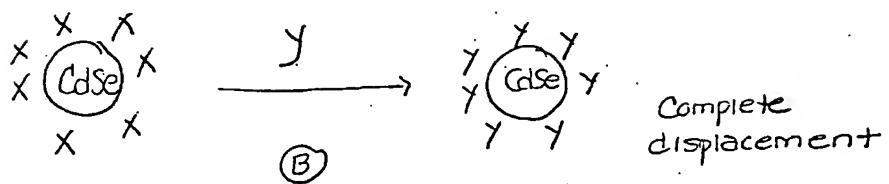
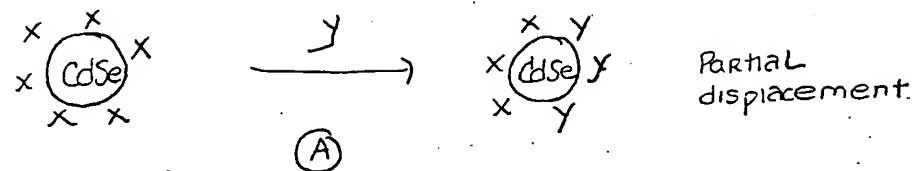
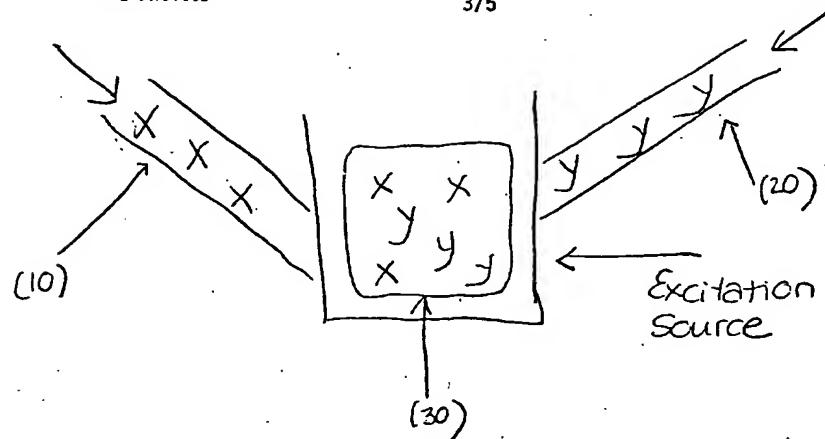
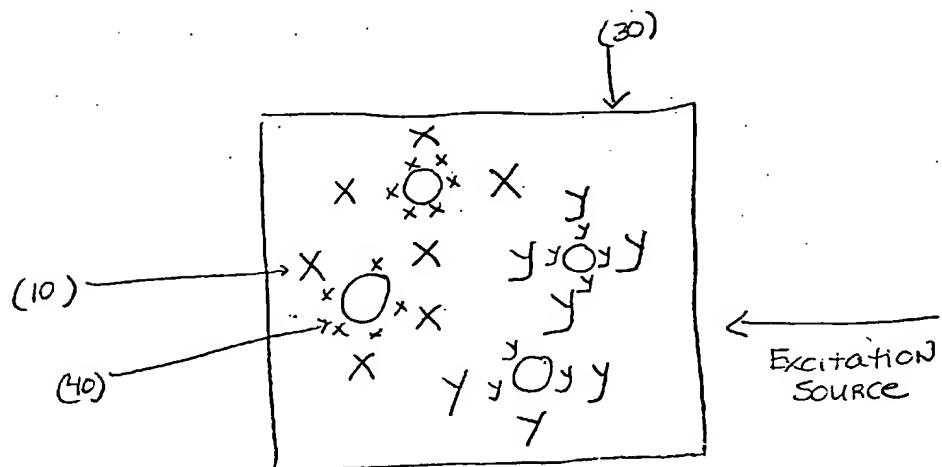


Figure 2

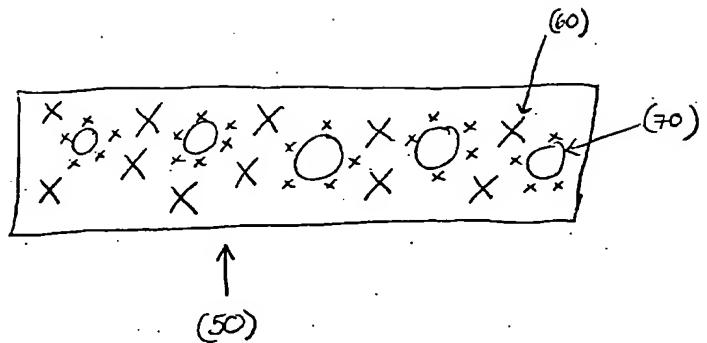


(A)

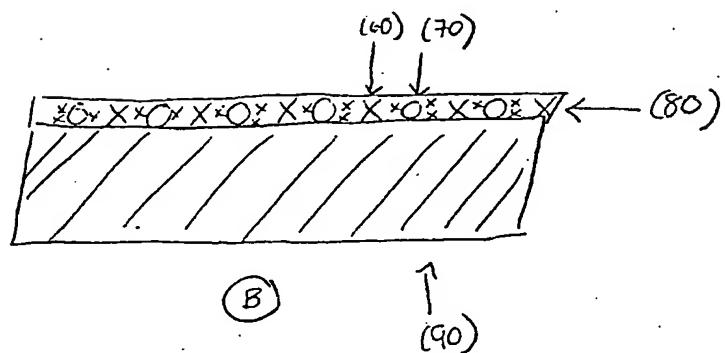


(B)

FIGURE 3



(A)



(B)

FIGURE 4

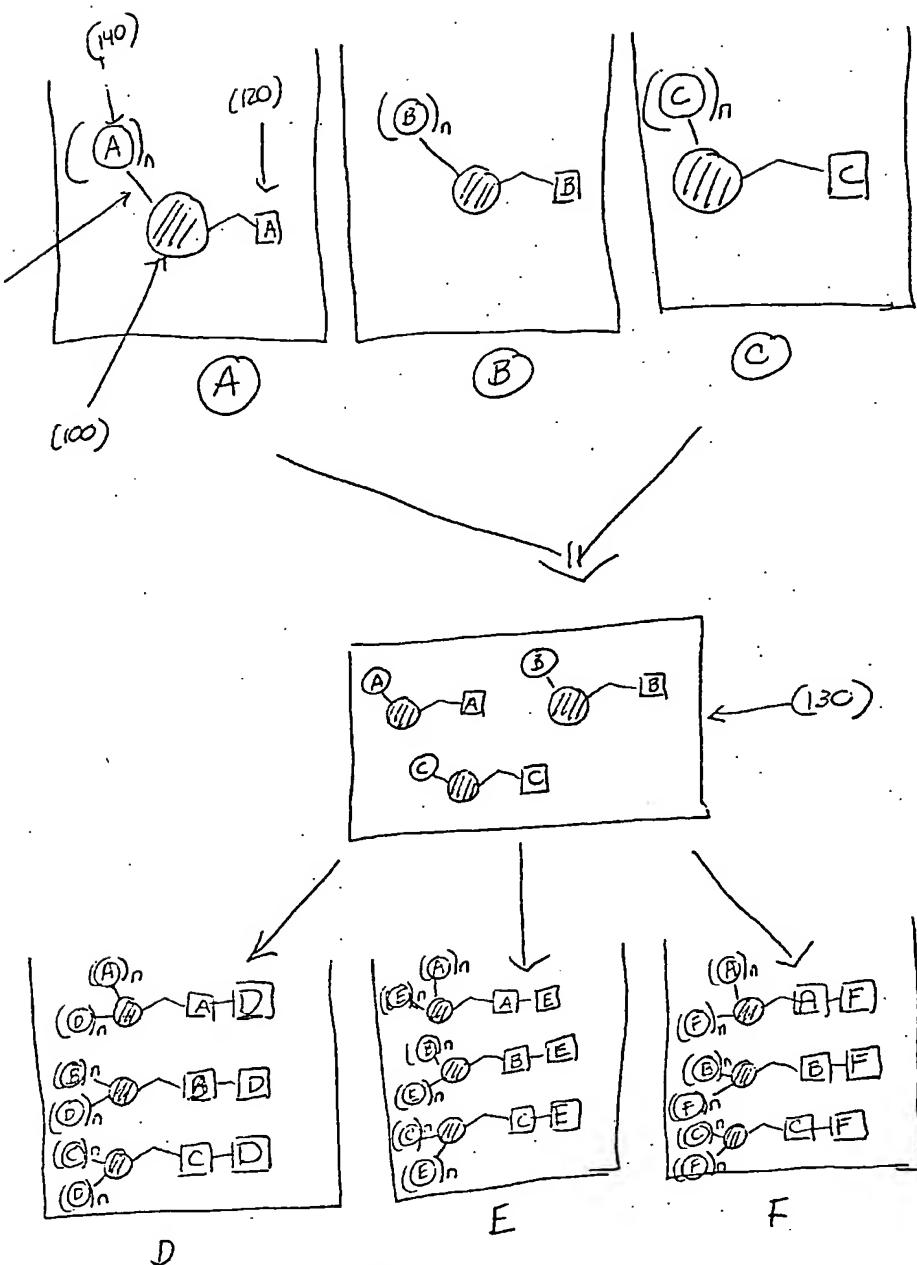


FIGURE 5



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification: C07H 21/00, G01N 21/64, G01N 33/58, G06K 7/14, G06K 19/06, H01L 33/00, H03M 7/48	A3	(11) International Publication Number: (43) International Publication Date:	WO 00/17103 30 March 2000 (30.03.2000)
(21) International Application Number: (22) International Filing Date:	PCT/US99/21373 17 September 1999 (17.09.1999)	Published	
(30) Priority Data: 09/160,458 24 September 1998 (24.09.1998) US 60/101,046 18 September 1998 (18.09.1998) US			
(60) Parent Application or Grant MASSACHUSETTS INSTITUTE OF TECHNOLOGY [/]; O. BAWENDI, Mounig, G. [/]; O. JENSEN, Klavs, F. [/]; O. BAWENDI, Mounig, G. [/]; O. JENSEN, Klavs, F. [/]; O. TSAO, Y., Rocky ; O.			

(54) Title: INVENTORY CONTROL
(54) Titre: GESTION D'INVENTAIRE

(57) Abstract

A novel encoding system, compositions for use therein and methods for determining the source, location and/or identity of a particular item or component of interest is provided. In particular, the present invention utilizes a collection of one or more sizes of populations of semiconductor nanocrystals having characteristic spectral emissions, to "track" the source or location of an item of interest or to identify a particular item of interest. The semiconductor nanocrystals used in the inventive compositions can be selected to emit a desired wavelength to produce a characteristic spectral emission in narrow spectral widths, and with a symmetric, nearly Gaussian line shape, by changing the composition and size of the semiconductor nanocrystal. Additionally, the intensity of the emission at a particular characteristic wavelength can also be varied, thus enabling the use of binary or higher order encoding schemes.

(57) Abrégé

L'invention concerne un nouveau dispositif de codage, des compositions associées utilisées et des procédés permettant de déterminer la source, l'emplacement et/ou l'identité d'un article ou d'un composant particulier. L'invention concerne notamment une collection d'au moins un effectif de populations de nanocristaux semi-conducteurs ayant des émissions spectrales caractéristiques, pour suivre la source ou l'emplacement d'un article d'intérêt ou pour identifier un tel article. Les nanocristaux utilisés dans les compositions selon l'invention peuvent être choisis pour émettre une longueur d'onde souhaitée afin de produire une émission spectrale caractéristique dans des largeurs spectrales étroites, et avec une caractéristique de ligne symétrique, quasi gaussienne, par le changement de la composition et des dimensions du nanocristal semi-conducteur. On peut en outre faire varier l'intensité de l'émission à une longueur d'onde caractéristique donnée, ce qui permet d'utiliser des programmes de codage d'ordre binaire ou supérieur.

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : C07H 21/00, H03M 7/48, G06K 7/14, G01N 21/64, G06K 19/06, G01N 33/58, H01L 33/00		A3	(11) International Publication Number: WO 00/17103
			(43) International Publication Date: 30 March 2000 (30.03.00)
(21) International Application Number: PCT/US99/21373		(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KJ, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).	
(22) International Filing Date: 17 September 1999 (17.09.99)			
(30) Priority Data: 60/101,046 18 September 1998 (18.09.98) US 09/160,458 24 September 1998 (24.09.98) US			
(71) Applicant (for all designated States except US): MASSACHUSETTS INSTITUTE OF TECHNOLOGY [US/US]; 77 Massachusetts Avenue, Cambridge, MA 02142 (US).			
(72) Inventors; and		Published	
(75) Inventors/Applicants (for US only): BAWENDI, Moungi, G. [-/US]; Apartment 2B, 285 Beacon Street, Boston, MA 02116 (US). JENSEN, Klavs, F. [-/US]; 103 Outlook Drive, Lincoln, MA 01773 (US).		With international search report.	
(74) Agent: NUGENT, Elizabeth, E.; Choate, Hall & Stewart, Exchange Place, 53 State Street, Boston, MA 02109 (US).		(88) Date of publication of the international search report: 31 August 2000 (31.08.00)	
<p>(54) Title: INVENTORY CONTROL</p> <p>(57) Abstract</p> <p>A novel encoding system, compositions for use therein and methods for determining the source, location and/or identity of a particular item or component of interest is provided. In particular, the present invention utilizes a collection of one or more sizes of populations of semiconductor nanocrystals having characteristic spectral emissions, to "track" the source or location of an item of interest or to identify a particular item of interest. The semiconductor nanocrystals used in the inventive compositions can be selected to emit a desired wavelength to produce a characteristic spectral emission in narrow spectral widths, and with a symmetric, nearly Gaussian line shape, by changing the composition and size of the semiconductor nanocrystal. Additionally, the intensity of the emission at a particular characteristic wavelength can also be varied, thus enabling the use of binary or higher order encoding schemes.</p>			
<p>(A)</p>			
<p>(B)</p>			

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav	TM	Turkmenistan
BF	Burkina Faso	GR	Greece		Republic of Macedonia	TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's	NZ	New Zealand		
CM	Cameroon		Republic of Korea	PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakhstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LJ	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCT/US 99/21373

A. CLASSIFICATION OF SUBJECT MATTER					
IPC 7 C07H21/00 H03M7/48 G06K7/14 G01N21/64 G06K19/06 G01N33/58 H01L33/00					
According to International Patent Classification (IPC) or to both national classification and IPC					
B. FIELDS SEARCHED					
Minimum documentation searched (classification system followed by classification symbols)					
IPC 7 G01N G06K H04N H01L					
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched					
Electronic data base consulted during the international search (name of data base and, where practical, search terms used)					
C. DOCUMENTS CONSIDERED TO BE RELEVANT					
Category	Citation of document, with indication, where appropriate, of the relevant passages				Relevant to claim No.
X	US 5 625 456 A (LAWANDY NABIL M) 29 April 1997 (1997-04-29) abstract; claims; figure 16 column 9, line 15 - line 59 column 10, line 58 -column 11, line 60 column 15, line 26 - line 45 column 16, line 27 - line 46 column 20, line 65 -column 21, line 43				1-12,23, 24,27
Y					25,26
A					28-30
X	WO 98 36376 A (SPECTRA SCIENCE CORP) 20 August 1998 (1998-08-20) page 6, line 4 - line 21 page 14, line 12 -page 15, line 9 ---				1-11
					-/-
<input checked="" type="checkbox"/> Further documents are listed in the continuation of box C.			<input checked="" type="checkbox"/> Patent family members are listed in annex.		
* Special categories of cited documents:					
"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed			"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "A" document member of the same patent family		
Date of the actual completion of the international search			Date of mailing of the international search report		
20 March 2000			28/03/2000		
Name and mailing address of the ISA			Authorized officer		
European Patent Office, P.O. 5815 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31651 epo nl. Fax: (+31-70) 340-3016			Hamdani, F		

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/21373

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KORTAN A R ET AL: "NUCLEATION AND GROWTH OF CdSe ON ZNS QUANTUM CRYSTALLITE SEEDS, AND VICE VERSA, IN INVERSE MICELLE MEDIA" JOURNAL OF THE AMERICAN CHEMICAL SOCIETY, US, AMERICAN CHEMICAL SOCIETY, WASHINGTON, DC, vol. 112, 1 January 1990 (1990-01-01), pages 1327-1332, XP000196554 ISSN: 0002-7863 the whole document	1,2, 5-10, 13-22
Y	—	25,26
X	US 5 770 299 A (DANNENHAUER FRITZ ET AL) 23 June 1998 (1998-06-23) column 3, line 63 -column 4, line 24	24,27
X	MIRMAL ET AL: "Fluorescence intermittency in single cadmium selenide nanocrystals" NATURE, vol. 383, 31 October 1996 (1996-10-31), pages 802-804, XP000877130 cited in the application the whole document	1,2, 5-10, 13-22
X	US 5 751 018 A (ALIVISATOS A PAUL ET AL) 12 May 1998 (1998-05-12) the whole document	1,2,5-10
X	WO 98 04740 A (UNIV NORTHWESTERN ;MIRKIN CHAD A (US); MUCIC ROBERT C (US); ELGHAN) 5 February 1998 (1998-02-05) abstract page 1, line 20 -page 14, line 6 page 51, line 22 -page 52, line 5	28-30
P,X	WO 98 46372 A (UNIV BROWN RES FOUND) 22 October 1998 (1998-10-22) abstract; claims page 1, line 18 -page 4, line 27 page 12, line 1 - line 16	1-12,23, 24,27
P,X	CHAN WCW ET AL: "Quantum Dot bioconjugates for ultrasensitive nonisotopic detection" SCIENCE, US, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE,, vol. 281, no. 281, 25 September 1998 (1998-09-25), pages 2016-2018-2018, XP002125871 ISSN: 0036-8075 the whole document	1-30
	—	-/-

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/21373

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	BRUCHEZ M JR ET AL: "Semiconductor nanocrystals as fluorescent biological labels" SCIENCE, US, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE,, vol. 281, no. 281, 25 September 1998 (1998-09-25), pages 2013-2016-2016, XP002125872 ISSN: 0036-8075 the whole document	1-30

2

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int. Application No	
PCT/US 99/21373	

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 5625456	A	29-04-1997	US 5448582 A US 5434878 A US 5825790 A US 5851225 A US 5903340 A US 5881886 A US 5943354 A AU 686773 B AU 1976395 A AU 693410 B AU 4536897 A AU 693750 B AU 4536997 A BR 9507130 A CA 2184367 A CN 1144022 A EP 0806066 A IL 112953 A JP 9510580 T WO 9526061 A ZA 9502209 A AU 1936795 A WO 9526060 A ZA 9502210 A	05-09-1995 18-07-1995 20-10-1998 22-12-1998 11-05-1999 16-03-1999 24-08-1999 12-02-1998 09-10-1995 25-06-1998 12-02-1998 02-07-1998 12-02-1998 23-09-1997 28-09-1995 26-02-1997 12-11-1997 16-08-1998 21-10-1997 28-09-1995 16-02-1996 09-10-1995 28-09-1995 11-12-1995
WO 9836376	A	20-08-1998	AU 6271798 A	08-09-1998
US 5770299	A	23-06-1998	DE 19541028 A EP 0771858 A JP 9202863 A US 5888444 A	07-05-1997 07-05-1997 05-08-1997 30-03-1999
US 5751018	A	12-05-1998	EP 0613585 A JP 7502479 T WO 9310564 A	07-09-1994 16-03-1995 27-05-1993
WO 9804740	A	05-02-1998	AU 4043497 A EP 0918885 A	20-02-1998 02-06-1999
WO 9846372	A	22-10-1998	US 5881886 A AU 6792798 A EP 0975443 A	16-03-1999 11-11-1998 02-02-2000